

Pictorial essay: Anatomical variations of paranasal sinuses on multidetector computed tomography-How does it help FESS surgeons?

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Abstract

With the advent of multidetector computed tomography (MDCT), imaging of paranasal sinuses prior to functional endoscopic sinus surgery (FESS) has become mandatory. Multiplanar imaging, particularly coronal reformations, offers precise information regarding the anatomy of the sinuses and its variations, which is an essential requisite before surgery.

Key words: Anatomical Variations; FESS; paranasal sinuses

Introduction

The success of functional endoscopic surgery depends on adequate knowledge of the complicated anatomy of the paranasal sinuses, which is variable. It is important to recognize the clinical and surgical significance of these variations. This pictorial essay aims to describe and clarify the common terminologies. Certain anatomic variations are thought to be predisposing factors for the development of sinus diseases and thus it becomes necessary for the radiologist to be aware of these variations, especially if the patient is a candidate for functional endoscopic sinus surgery (FESS).

Technique of CT Scan for FESS

At our institution, we performed the scan with 64 slice

multidetector computed tomography (MDCT) with the patient in supine position. Axial images of the sinuses are acquired with 0.625 collimation and from this raw data sagittal and coronal reformations are obtained using both soft tissue and bone window algorithms.

Anatomy

The lateral nasal wall contains three bulbous projections, namely the superior, middle, and inferior turbinates (conchae), which divide the nasal cavity into superior, middle, and inferior meati. The superior meatus drains the posterior ethmoid air cells and the sphenoid sinus via the sphenoethmoidal recess. The middle meatus drains the frontal sinus via the nasofrontal recess, the maxillary sinus via the maxillary ostium, and the anterior ethmoid air cells via the ethmoid cell ostia. The nasolacrimal duct drains into the inferior meatus.

Osteomeatal Unit

The osteomeatal unit (OMU) includes the (1) maxillary sinus ostium, (2) ethmoid infundibulum, (3) anterior ethmoid air cells, and (4) frontal recess [Figure 1A]. They are referred to as the anterior sinuses. The OMU is the key factor in the pathogenesis of chronic sinusitis. The

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ethmoid sinus is the key sinus in the drainage of the anterior sinuses. It is vulnerable to trauma during surgery due to its close relationship with the orbit and the anterior skull base.

Agger Nasi Cell-what are They?

This cell is present in nearly all patients and is an ethmoturbinal remnant. It is the most anterior ethmoidal air cell and extends anteriorly into the lacrimal bone. It lies anterior, lateral, and inferior to the frontal recess and borders the primary ostium of the frontal sinus [Figure 1B]. A good view of frontal recess is obtained when the agger nasi cells are opened. Thus its size may directly influence the patency of the frontal recess and the anterior middle meatus.

Frontal Recess

The frontal recess refers to the narrowest anterior air channels that communicate with the frontal sinus. They are common sites of inflammation. The walls of the recess are formed by the agger nasi cell anteriorly, the lamina papyracea laterally, and the middle turbinate medially [Figure 1B]. This recess opens into the middle meatus in 62% of subjects and into the ethmoid

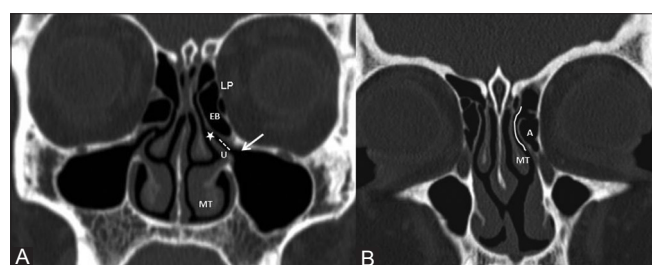


Figure 1 (A, B): (A) Coronal CT scan shows the osteomeatal complex which comprises of – infundibulum (dotted line), hiatus semilunaris (asterisk), maxillary ostium (arrow) and Ethmoidal bulla (EB). MT-middle turbinate, LP-lamina papyracea. (B) Coronal CT images reveals a prominent agger nasi cell (A) inferior and lateral to the nasofrontal recess (solid curved line). The medial relationship of the recess is formed by the middle turbinate (MT)



Figure 3: Coronal CT scan shows that the ethmoid roofs are almost in the same plane as the cribriform plate (double arrow) – Keros type I

infundibulum in 38%.^[1] On coronal CT scan, this recess is identified superior to the agger nasi cell.^[2]

Ethmoid Infundibulum

The ethmoid infundibulum is bounded anteriorly by the uncinate process, posteriorly by the anterior walls of the bulla ethmoidalis, and laterally by the lamina papyracea [Figure 1A]. It opens into the middle meatus medially through the hiatus semilunaris. On coronal CT scan, the bulla ethmoidalis is seen superior to the ethmoid infundibulum. The maxillary sinus ostium is seen to open into the floor of the infundibulum

Why is the Ethmoid Roof Anatomy Important?

The ethmoid roof is of critical importance for two reasons. First, it is most vulnerable to iatrogenic cerebrospinal fluid

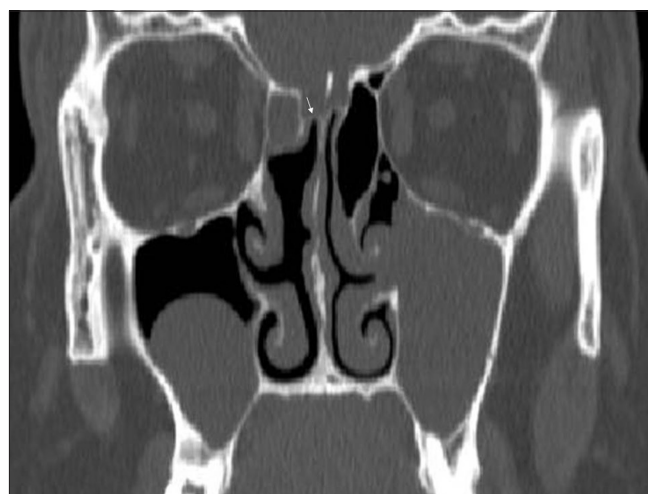


Figure 2: Coronal CT scan shows asymmetry in the height of the ethmoid roof (arrow), with the right roof being lower than the left. There is high incidence of intracranial injury during FESS due to this anatomical variation

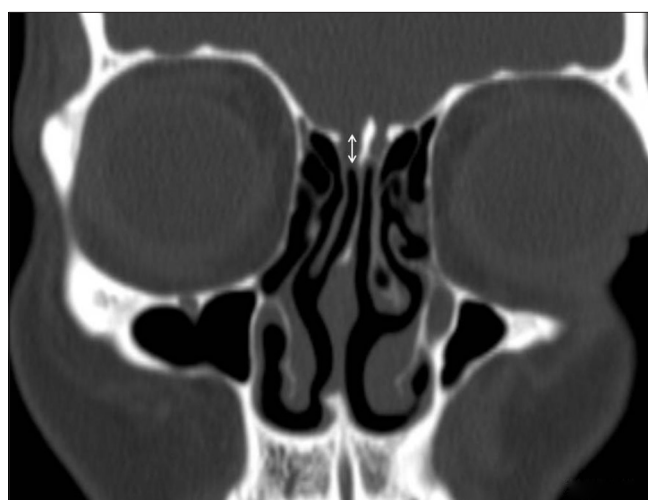


Figure 4: Coronal CT reveals the olfactory fossae are deeper and the lateral lamellae are longer (double arrow) – Keros type II

leaks. Second, the anterior ethmoid artery is vulnerable to injury, which can cause devastating bleeding into the orbit. During FESS, intracranial injury can occur on the side where the position of the roof is relatively low^[3] [Figure 2].

The depth of the olfactory fossa is determined by the height of the lateral lamella of the cribriform plate, which is part of the ethmoid bone. In 1962, Keros had classified the depth of the olfactory fossa into three types, that is, Keros type I: <3 mm [Figure 3], type II: 4-7 mm [Figure 4], and type III: 8-16 mm [Figure 5]. Kero type III is most vulnerable to iatrogenic injury.^[4-6]

What are Onodi Cells?

These are posterior ethmoidal cells extending into the sphenoid bone [Figure 6], either adjacent to or impinging upon the optic nerve.^[7] When these Onodi cells abut or surround the optic nerve, the nerve is at risk when surgical excision of these cells is performed. It is also a potential cause of incomplete sphenoidectomy.



Figure 5: Coronal CT shows that the olfactory fossae are very deep (double arrow) – Keros type III

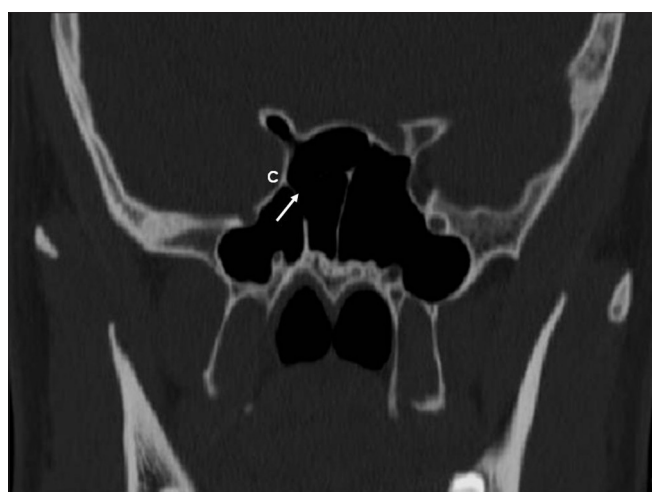


Figure 7: Coronal CT shows the sphenoid septum deviated to the right (arrow); it is seen to insert over the bone covering the right internal carotid artery (C)

What are the Important Features of the Sphenoid Sinus?

The intersphenoid septum is deflected to one side, attaching to the bony wall covering the carotid artery, and thus arterial injury may result when the septum is avulsed during surgery [Figure 7]. The artery may bulge into the sinus in 65-72% of patients. There may be dehiscence/absence of the thin bone separating the artery and the sinus in 4-8% of cases.^[8]

Agenesis of the sphenoid sinus may be seen [Figure 8].

The pterygoid canal [Figure 9] or the groove of the maxillary nerve [Figure 10] may project into the sphenoid sinus, which may result in trigeminal neuralgia secondary to sinusitis.

Anterior clinoid process pneumatization [Figure 9] is associated with type II and type III optic nerve and predisposes this nerve to injury during FESS.

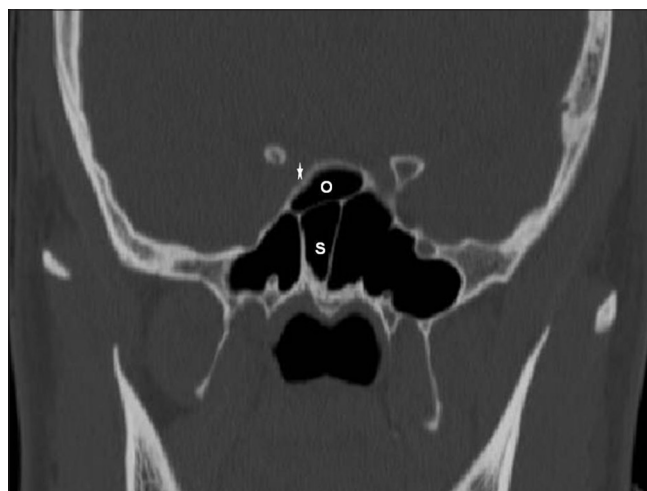


Figure 6: CT PNS, coronal view, shows a septate Onodi cell (O) extending superiorly and laterally to the sphenoid sinus (S). Also seen is the extension of the Onodi cell laterally to that of the optic canal (star)



Figure 8: Coronal CT shows agenesis of the sphenoid sinus

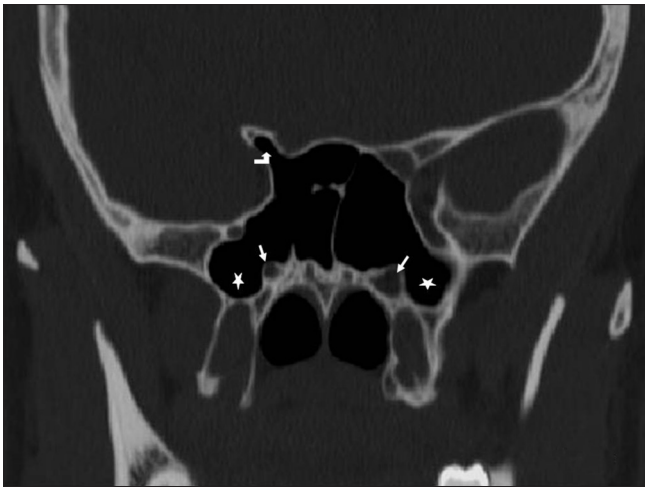


Figure 9: Coronal CT image reveals pneumatization of the anterior clinoid process (bent up arrow) and bilateral pterygoid processes (star), with protrusion and partial dehiscence of bilateral vidian nerves (arrow)



Figure 10: Coronal CT showing pneumatized bilateral greater wing of sphenoid (star), with protrusion of maxillary nerve bilaterally (arrow). The left maxillary nerve is dehiscent. Note also the protuberant vidian nerves bilaterally (downward curved arrow)



Figure 11: Coronal CT showing type I optic nerve (arrows) the nerve is seen to course immediately adjacent to the sphenoid sinus, without contact with the posterior ethmoid air cell

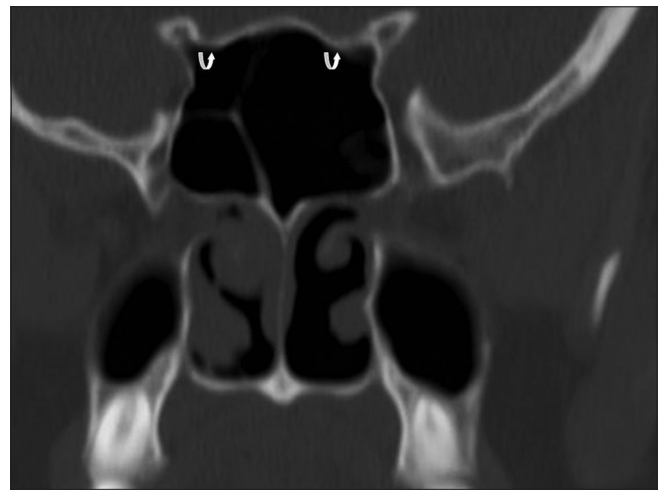


Figure 12: Coronal CT showing type II optic nerve (curved arrows) causing an indentation of the sinus wall, but without contact with the posterior ethmoid air cell



Figure 13: Coronal CT shows type III optic nerve (arrows) where more than 50% of the nerve is surrounded by air

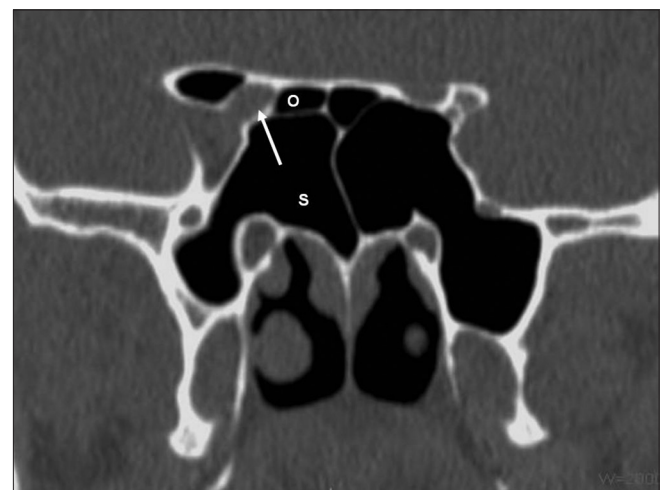


Figure 14: Coronal CT showing type IV optic nerve on the right (arrow) -The nerve course lies immediately adjacent to the sphenoid and posterior ethmoid sinus. O: Onodi cell; S: Sphenoid sinus

What are the Variations of the Optic Nerve?

The optic nerve, carotid arteries, and vidian nerve develop prior to the paranasal sinuses, and are responsible for the congenital variations in the walls of the sphenoid sinus. Delano, *et al.*, categorized the various relationships between the optic nerve and posterior paranasal sinuses into four groups,^[9] as follows:

- Type I: The most common type, it occurs in 76% of patients. Here, the nerve courses immediately adjacent to the sphenoid sinus, without indentation of the wall or contact with the posterior ethmoid air cell [Figure 11].
- Type II: The nerve courses adjacent to the sphenoid sinus, causing an indentation of the sinus wall, but without contact with the posterior ethmoid air cell [Figure 12].

- Type III: The nerve courses through the sphenoid sinus with at least 50% of the nerve being surrounded by air [Figure 13].
- Type IV: The nerve course lies immediately adjacent to the sphenoid and posterior ethmoid sinus [Figures 14 and 15].

Delano, *et al.*, found that 85% of optic nerves associated with a pneumatized anterior clinoid process were of type II or type III configuration, and of these, 77% showed dehiscence [Figure 16], indicating the vulnerability of the optic nerve during FESS.

The sphenoid sinus septa may be attached to the bony canal of the optic nerve, predisposing the nerve to injury during surgery [Figure 17].

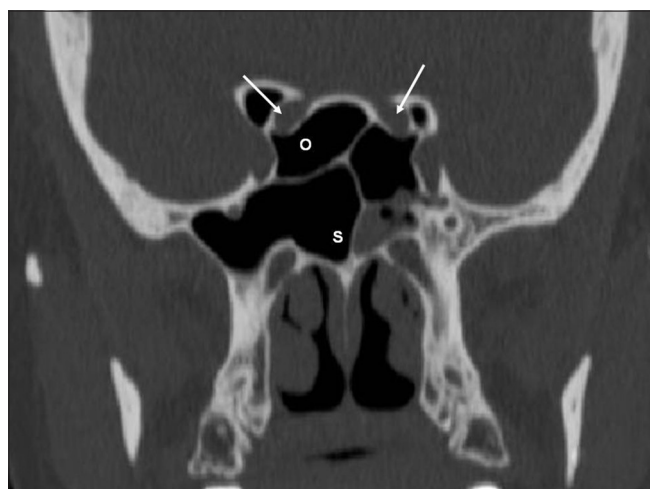


Figure 15: Coronal CT showing type IV optic nerve bilaterally (arrows). O: Onodi cell; S: Sphenoid sinus

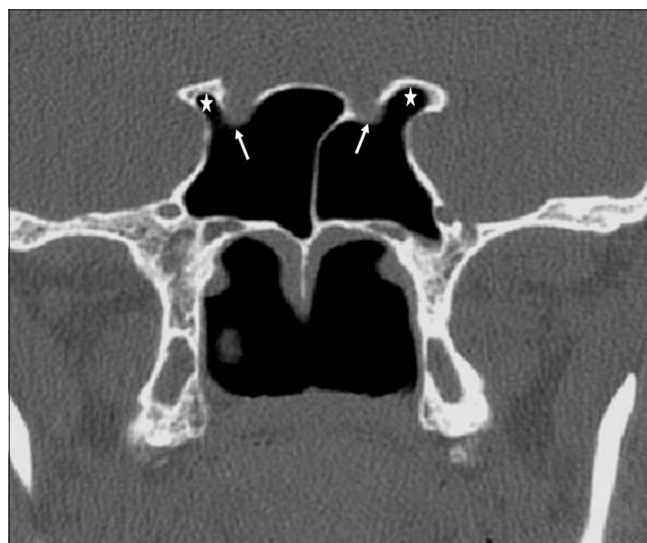


Figure 16: Coronal CT shows pneumatisation of anterior clinoid process (stars) with type III optic nerve (stars) with bony canal dehiscence bilaterally



Figure 17: Coronal CT showing sphenoid septa (arrow) attached to the bony walls of type III optic nerve bilaterally (stars)

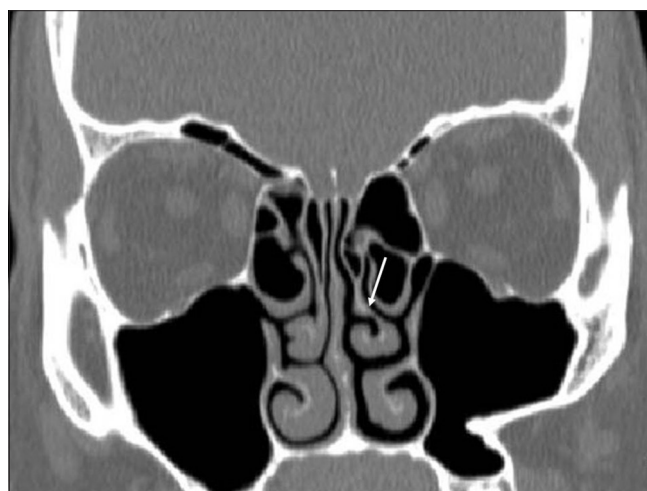


Figure 18: Coronal CT showing paradoxical left middle turbinate (arrow)

What are the Middle Turbinate Variations?

(a) Paradoxical curvature: Normally the convexity of the middle turbinate is directed medially toward the nasal septum. When the convexity is directed laterally, it is termed a paradoxical middle turbinate [Figure 18]. Most authors agree that the paradoxical middle turbinate can be a contributing factor to sinusitis.

(b) Concha bullosa: This is an aerated turbinate, most often the middle turbinate. When pneumatization involves the bulbous portion of the middle turbinate, it is termed concha bullosa [Figure 19]. If only the attachment portion of the middle turbinate is pneumatized, it is termed lamellar concha [Figure 20]. A concha bullosa may obstruct the ethmoid infundibulum.

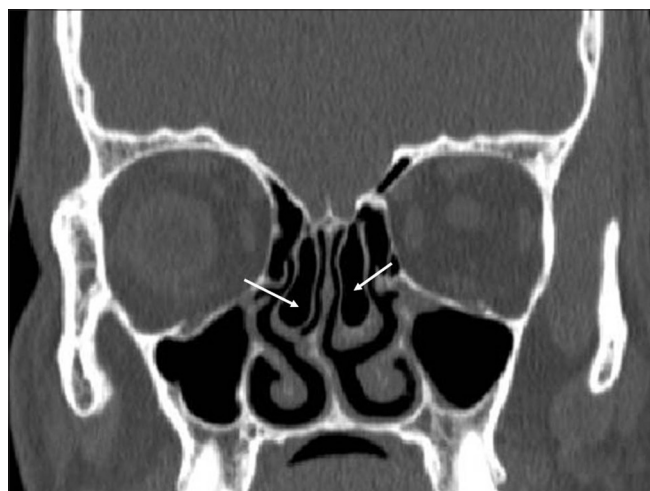


Figure 19: Coronal CT showing pneumatized bulbous portion of middle turbinate—concha bullosa—bilaterally (arrows)

What are the Variations of the Uncinate Process?

On coronal CT scan, the posterior sections show the uncinate process as a thin bone attached to the inferior turbinate inferiorly, with a posterior free edge. In the anterior sections, it is attached to the skull base superiorly, to the middle turbinate medially, and to the lamina papyracea or the agger nasi cells laterally.

The uncinate process may be medialized, lateralized, or pneumatized/bent. Medialization occurs with giant bulla ethmoidalis. Lateralization of the uncinate process may obstruct the infundibulum. Pneumatization of the uncinate process (uncinate bulla) [Figure 21] may be seen in 4% of the population^[10] and is rarely the cause obstruction of the infundibulum.^[11]

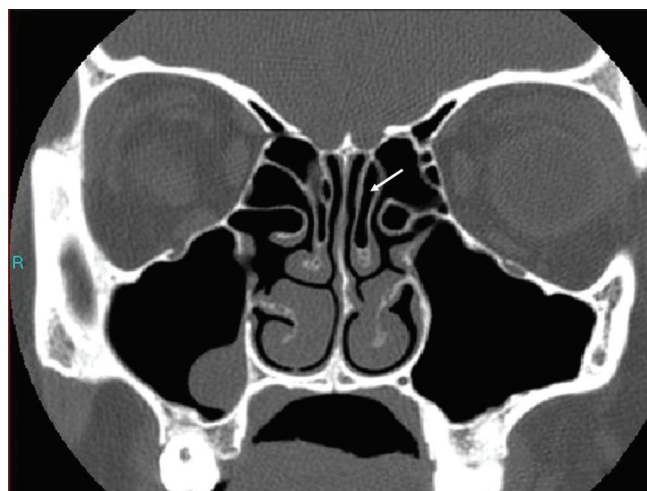


Figure 20: Coronal CT showing left lamellar concha (arrow)

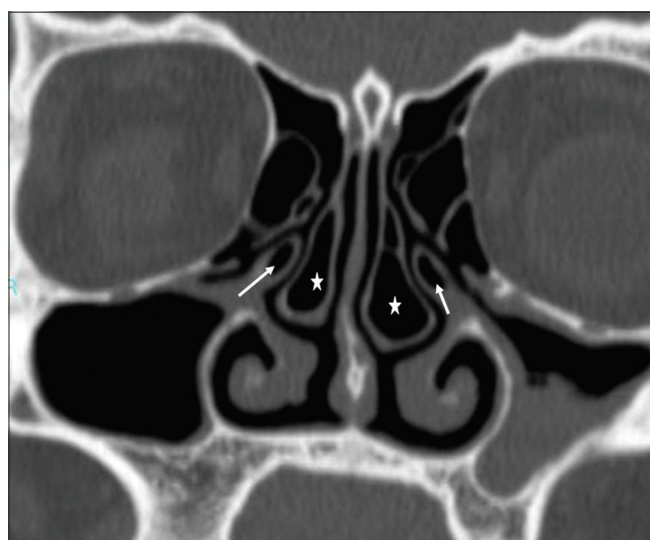


Figure 21: Coronal CT showing bilaterally pneumatized uncinate process (arrow). Also note bilateral concha bullosa (stars)

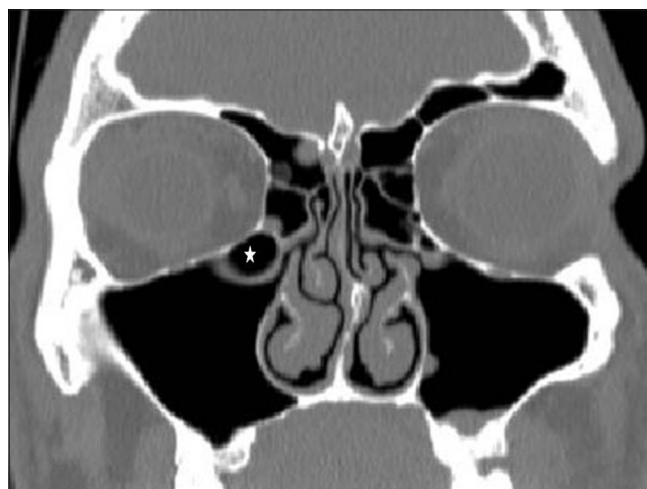


Figure 22: Coronal CT shows right Haller cell (star). These cells may contribute to narrowing of the infundibulum

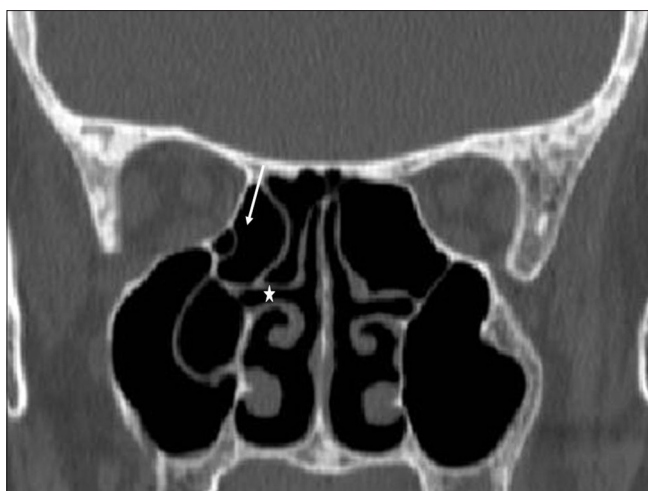


Figure 23: Coronal CT shows ethmoid bulla (arrow) superior to the ethmoid infundibulum (star)

Haller Cells—What are They?

These are also called infraorbital ethmoid cells and are pneumatized ethmoid air cells [Figure 22]. They project along the medial roof of the maxillary sinus and the most inferior portion of the lamina papyracea, below the ethmoid bulla, and lie lateral to the uncinate process. These cells contribute to the narrowing of the infundibulum and may compromise the ostium of the maxillary sinus, thus contributing to recurrent maxillary sinusitis.^[12,13]

What is Bulla Ethmoidalis?

This is the largest and most prominent anterior ethmoid air cell. It is related laterally to the lamina papyracea. It may fuse with the skull base superiorly and with the lamella basalis posteriorly. On coronal CT scan it is seen superior to the ethmoid infundibulum [Figure 23]. The degree of pneumatization varies, and failure to pneumatize is termed torus ethmoidalis. A 'giant bulla' may fill the entire middle meatus and force its way between the uncinate process and the middle turbinate.

Posterior Nasal Septal Air Cell

Air cells may be seen in the posterosuperior portion of the nasal septum and may communicate with the sphenoid sinus [Figure 24]. Any inflammatory disease that occurs within the paranasal sinus may affect these cells. It can resemble a cephalocele. CT scan and magnetic resonance imaging (MRI) are useful to differentiate this entity.

Aerated Crista Galli

The crista galli is normally bony. When aerated, it may communicate with the frontal recess, causing obstruction of

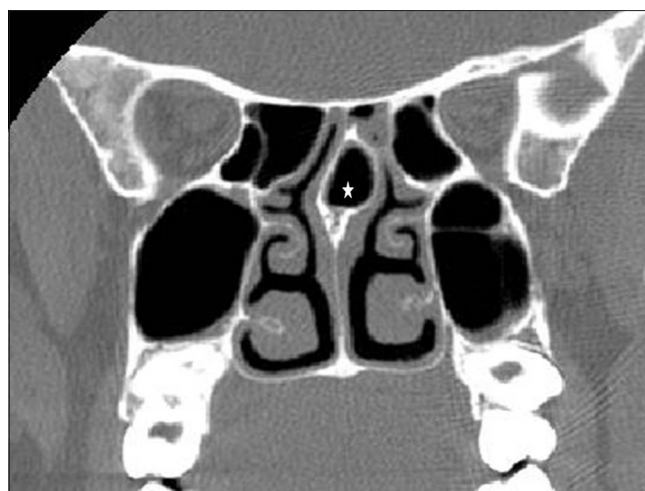


Figure 24: Coronal CT showing posterior nasal septal air cell (star)

the ostium and thus lead to chronic sinusitis and mucocoele formation. It is crucial to identify and differentiate this from an ethmoid air cell before surgery to avoid inadvertent entry into the anterior cranial fossa.

Conclusion

To summarize, a thorough understanding of the paranasal sinus anatomy and its variations is important and essential for FESS surgeons. The radiologist plays a vital role in providing the information required by the surgeons.

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